

A Case Study of A Navigator's Sea Aptitude Using Body Response to Visual Simulation

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Abstract - We describe the relationship between a navigator's aptitude and the body's center of gravity and/or heart rate variability while using a ship's bridge simulator. Navigator aptitude relates directly to *kansei* (the sense for ship handling/common sense) because his understanding of what is right or wrong for the ship affects his decisions. Common sense is usually employed by professional mariners; however, mistakes sometimes occur on training or merchant ships with multinational crews. Japanese maritime colleges have made entrance examinations and sea aptitude training easier. But professors need to pinpoint student aptitude by developing an evaluation method of *kansei* measuring the center of gravity and/or heart rate variability utilizing the effects of "Human Computer Interaction" on a simulator with a visual system.

Key Words- Sea aptitude, Body response, Subliminal mind, *Kansei*.

INTRODUCTION

Six kinds of licenses exist in Japan for the navigator of a ship. In order to reach the rank of captain which requires a first grade license, the navigator needs at least eight years' experience. Students attend one of two universities or five colleges in order to obtain a third grade license to operate a merchant ship. By graduation each student must have one year's experience aboard a training vessel and must have a passing grade on the government-required oral examination. Moreover, students must pass the eye exam, the hearing exam, and the functions exam before receiving their licenses.

Bridge Resource Management (BRM) teams live and work in the closed space aboard ship. Nationalities of bridge teammates sometimes differ making it difficult to follow individual customs. Clearly, a strong personality is required to function with this type of stress. The Japanese maritime schools previously required students to live in dormitories in order to help acclimate students to the stress associated with living in close quarters. Now, that attitude is considered outdated and not conducive to encouraging students to cooperate on BRM teams. Additionally, the Japanese maritime program strives to help students who have difficulty breathing under the kind of stress sometimes seen on a bridge by having students work repeatedly on the bridge simulator. Despite these efforts, no evaluation method yet exists to determine the aptitude and the *kansei* of future navigators. We propose to develop an evaluation method using the student's center of gravity and/or heart rate

variability while the student is using a bridge simulator with a visual field.

Human nature and potential, not knowledge, are basic factors that contribute to the development of a good navigator. By effective utilization of the bridge simulator, a rather complex computer system with a visual field that can mimic accidents at sea, different sea conditions, different ship maneuverability, etc. we can test student reactions, thus evaluating student judgement under various types of stress. We combine aptitude and the concept of *kansei* to create a new term: "ship-friendly navigator" (e.g., a navigator who has the art and ability to handle a large ship under stressful conditions created by weather conditions, the multinational make-up of the BRM, the handling of the "virtual ship", and the student's own level of fear). Such an evaluation method is attracting the attention of educators interested in using computer models to recreate real-life situations so students can be taught effective reactions to those situations. Concurrently, there is also interest in knowing the student's *kansei*, or sensibility about shiphandling.

BACKGROUND

The evaluation of the navigator's *kansei* and aptitude is done to discover his personal characteristics. We utilize the simulator to identify the necessary characteristics of a successful navigator. The method is simple: the student navigator looks at a computer-generated picture on the simulator while the investigator measures his center of gravity and heart rate, using their variability as the evaluation index.

1. *Kansei*

Kansei is the art of "sensibility" or "common sense". Just as an artist or musician has this sensibility [1] when creating, professional navigators also have it when steering a large ship. Of course, sensibility (or *kansei*) is not identical for each of those three behaviors. Nevertheless, it exists; and the artist knows when he possesses it just as the professional navigator knows when he possesses it.

Kansei information is divided into four kinds - 'symbol', 'parameter', 'pattern', and 'image'. We can express the symbol in an adjectival word like 'warm'. We can express the parameter by a vector in the coordinate data made by adjectival words using factor analysis. Pattern is difficult to describe in the same way that it is difficult to describe the feel of fabric or the tonal quality of an instrument. Image is difficult to exteriorize just as a mental picture or inspiration is [1], [2].

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Research on *kansei* attempts to identify a person's sensibility while performing a certain activity. Psychological and physiological methods are used to determine the kinds of *kansei* information processing used by student navigators. The psychological method measures the relationship between an impulse (e.g., light, sound, heat, music, and picture) to the human and the response to it [3], [4]. Emotion is evaluated by Semantic Differential assessment [5]. The physiological method measures the heart rate, respiration, skin temperature, blood pressure, etc. of the subject of an investigation [6], [7].

The idea of *kansei* is not the same as human error [8], [9] as revealed in human performance models. Research to identify human factors in transport systems except ships has been successful, especially in the aerospace and space fields [10]. However, a ship is different from other systems because the navigator is never in a fixed operational seat and members of the BRM team move freely on the bridge.

II. Body Balance

Humans maintain body balance unconsciously. The stability of the gravity center sometimes differs with age, gender, and daily conditions. The gravity center is used to evaluate the mechanism of 'homeostasis' [11]. One consequence of being "off balance" at sea is motion sickness which has been investigated by many researchers [12], [13]. Seasickness can also be induced by the simulator's 'apparent' motion [14], [15].

Seasickness occurs as "a result of a conflict in the inner ear caused by the erratic motion of the ship" [16]. The inner ear, including the semicircular canals which function as balance organs, "detects changes in linear and angular acceleration as the body bobs with the boat" [16] but the eyes perceive a relatively stable environment in the cabin. We have researched the relationship of seasickness to a bridge simulator by examining the factors of the picture on the simulator screen: the horizontal angles, the rolling and so on. They discovered that it is entirely possible to induce seasickness by manipulating the picture on the screen [17]. Simulators are commonly used in maritime schools to educate students in the value of teamwork [18], [19] and to teach shiphandling and accident analysis skills [20].

EVALUATION OF A NAVIGATOR'S ART USING A SIMULATOR

I. How to Bring Out the Kansei of A Navigator

In Japan, research into *kansei* is popular among artists and musicians [1]; however, this research has not yet been attempted among navigators. The concept of *kansei* among navigators has been proposed in the definition of navigational information as the navigator-centered navigational information model (TPK model) on three dimensions of space consisting of: 'Time (T):x-axis,' 'Position (P): y-axis' and 'Kansei (K): z-axis' (Fig.1) [21]. The navigator's performance model [22], [23] is meant to be similar to the mental workload model already in place. This model shows the importance of individual aptitude. For example, humans do not always exhibit the same sensitivity,

but rather display differences in judgement when confronted with the same situation. Sensibility aptitude is crucial to a successful navigator who must often make quick decisions under stress (time pressure).

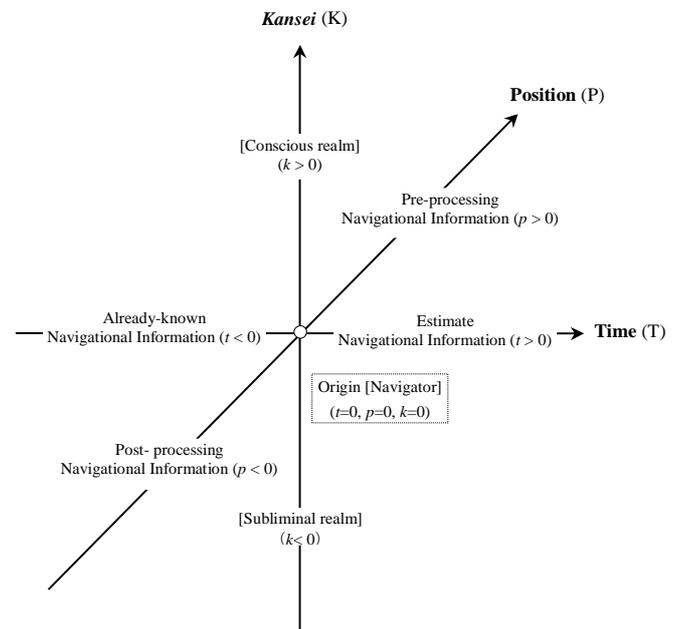


FIGURE 1
TPK MODEL. (THE NAVIGATOR CENTERED NAVIGATIONAL INFORMATION MODEL.).

The physical and physiological response to the picture made by a simulator reveals the student's sensibility (*kansei*) at the unconscious level or the subliminal level. Of course, the picture must reproduce virtually the field of vision which a navigator would ordinarily see in order to mimic reality. As part of the advanced directions for using a simulator, we propose a special evaluation method to test the navigator's *kansei* while using the simulator. We have adopted the new term 'sea-friendly' to mean the student's feeling for the sea as one factor of *kansei*. Our idea is to utilize a reflex body response to the simulated picture of the sea generated by a sophisticated computer in order to assess the feelings cultivated by experience on a ship.

The method involves looking at the rolling picture of different wave heights (Fig 2.). The procedure is as follows:

- 1) The tester shows a picture (consisting of sea, sky, and ship's bow) mimicking the rolling of a ship from one to eight meters' wave height. The virtual image has the ship moving at a constant speed and course without current/wind effects.
- 2) The subject looks at the rolling picture for three minutes, rests for one minute, and then looks at a picture showing a zero meter wave height (flat sea) for three minutes. The tester needs the rest to break off the experiment and needs the zero meter picture to cancel the influence of the previous rolling picture on the subject.
- 3) The tester measures the gravity center, heart rate variability and subjective values. These indices are

popular for physical, psychological, and subjective evaluations. Moreover, evaluations with multiple indices produce more accurate results.

- 4) The tester analyzes the characteristics of the gravity center (length and ratio of back and forth to right and left), heart rate (mean and ratio of standard deviation and mean) and subjective values and comments.

The characteristics of the indices clearly differ between specialists and beginners. The specialists can recognize the difference in feeling between the virtual sea and the real sea, and their responses appear in the indices (Fig.3). The problem with this method is that no clear relationship has been shown yet between the student's year of sea training and the accuracy of predicting the student's success at sea once he receives his third grade license.

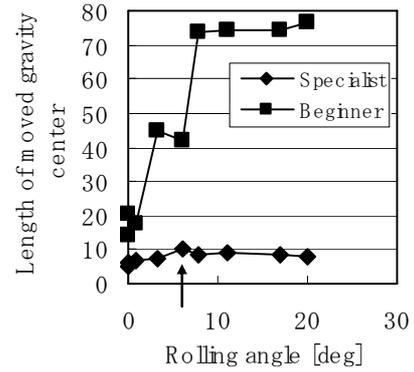


FIGURE 3
BODY RESPONSES TO THE PICTURES (SPECIALIST AND BEGINNER); A SPECIALIST FELT SOMETHING WAS WRONG IN A VIRTUAL SEA SHOWN BY AN ARROW.

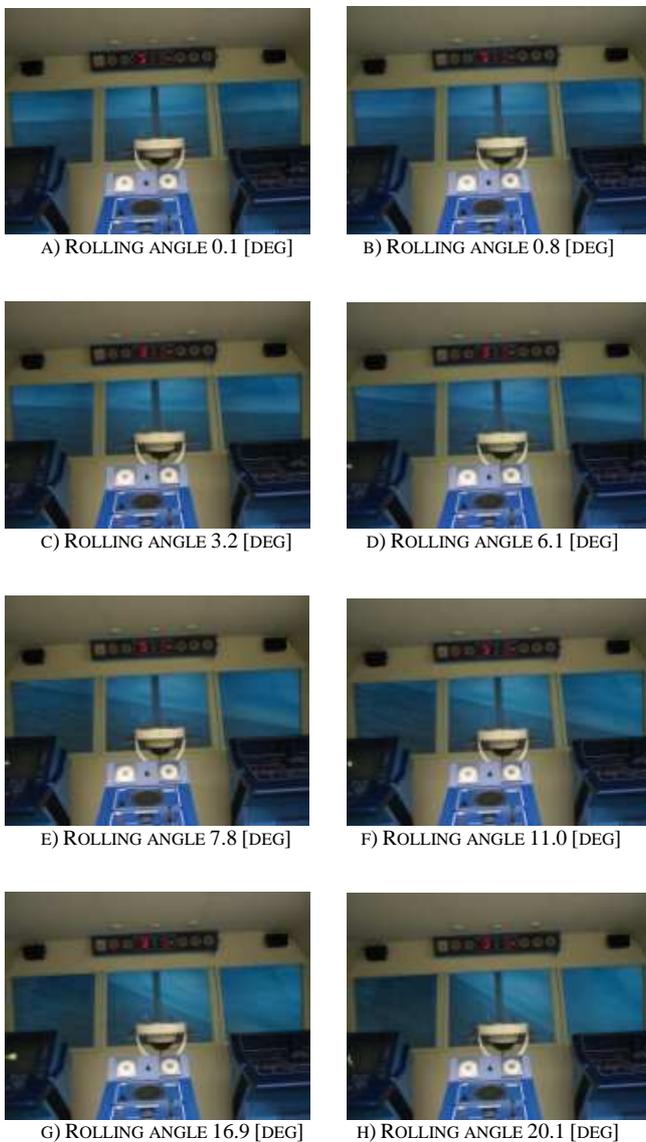


FIGURE 2
PICTURES OF THE ROLLING ARE CONTROLLED BY WAVE HEIGHTS FROM ONE TO EIGHT METERS.

II. How to Evaluate the Aptitude of A Navigator

In Japan, the aptitude test for the navigator is conducted in an interview at a shipping company by an interviewer who has a lot of experience on ships and in personnel affairs. The schools never examine the navigator for his 'sea-friendly' aptitude except in a standard physical examination which is required to sail aboard the training vessel. In other words, schools guide students to become good navigators only by requiring them to live in dormitories and participate in school activities. Some schools are better than others at evaluating the student's judgements in these activities.

Professional mariners sometimes say that students have a weak or a strong aptitude for life at sea. Here they are generally referring to whether students get seasick easily (weak) or not (strong). This matter is important for the navigator's mentality and influences the determination of whether or not he is 'ship-friendly.' Educators in the maritime colleges have the responsibility of guiding students to become competent navigators and so, obviously, wish to evaluate their overall aptitude for life at sea.

We propose to evaluate the aptitude of the navigator by using the simulator to study the student's reactions to virtual sea situations. The method requires looking at a moving picture of a wave. The procedure is similar to the previous one except that we use a wave height of zero meters as the picture and the gravity center (standard deviation (SD), average, max-min) as the index. By using this method, we have learned that the characteristics of the indices differ between the weak person (G) and the strong person (A) (Fig.4, Fig.5). The weak person exhibits two tendencies: one fluctuates largely; the other increases the rate of fluctuation. A problem with this method is that no clear relationship between the training year aboard the ship and the accuracy of predicting a navigator's success has been demonstrated yet.

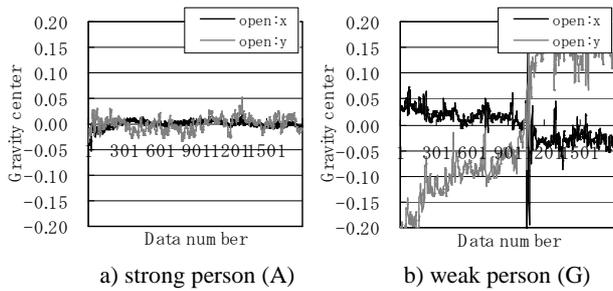


FIGURE 4
FLUCTUATION OF THE BODY GRAVITY CENTER.

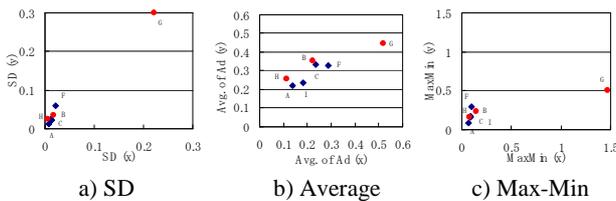


FIGURE 5
THE BODY GRAVITY CENTER (SD, AVERAGE, MAX-MIN).

FUTURE TRENDS

Important factors for determining a navigator's possible success are the ship bridge simulator and the navigator's own *kansei*. The new proposed evaluation method using the simulator and the objective index (physical, physiological, and psychological evaluation) of ship bridge design and educational framework attracts navigators interested in improving safety at sea.

I. Evaluation of Ship-Friendly Bridge Design

The evaluations of the navigator's art with multiple indices of the psychological and the physiological approach is realistic in comparison to the current method which is dependent on the subjective experience of specialists. Bridge design also depends on the experience of designers and shipbuilders. Bridge design influenced by actual working conditions is important to achieve safe navigation; while hull shapes depend on cargoes (e.g., oil, gas, ore, and passengers). Bridge Resource Management teams try to use any given design efficiently; therefore, bridge design can have a direct or indirect effect upon the *kansei* of the navigator. Any design that reflects the 'art' of sailing can contribute to the prevention of unconscious human errors. The simulator combined with the physiological index is useful for the objective evaluation of bridge design.

II. New Educational Framework for Becoming A Navigator

The educational method can be divided into "lecture type" and "practice type." In the lecture type, students are passive, meaning they just receive knowledge while the instructor lectures on the main points of a theory. Students are evaluated by written examination. In the practice type, students are active, meaning they must participate while the educator shows them how to do something (e.g., shiphandling technique, seamanship, etc.). Success or failure

is evaluated by specialists who observe the student performing a function. However, such examinations and observations provide only superficial results. The hidden potential of *kansei* is not judged. Yet *kansei* is an important component for a complete evaluation of a student taking a practice-type course because the evaluation depends on the experience of the specialists and therefore is not necessarily objective. Consequently, the educator needs to learn the points of the specialists' art and then design the framework of the art [24]. By using a simulator to induce physiological responses to an artificial environment that simulates a real environment, the educator can get a more complete sense of a student's aptitude for operating a vessel under several different kinds of pressure (e.g., cross-cultural stress, seasickness, time pressure, etc).

CONCLUSIONS

The use of a simulator in the education, training, and research at maritime schools and shipping companies, and its efficiency in education and training are recognized as effective at reproducing reality by users (educators and specialists). However, because education using the simulator is still evaluated based on the experience of specialists, it is not fully objective. The art of a navigator is an historical legacy but the outline of the art has not been clarified despite being handed on from sailor-to-sailor. Additionally, each student's *kansei* has a direct effect upon his success at sea. The great advantage of the simulator is that it offers educators the ability to reproduce the same situation for all students. The fixed environment makes it relatively easy to determine the *kansei* which can be influenced even by a little change in natural surroundings. The evaluation of *kansei* and aptitude by using the physiological response to the simulator with the quantitative indices for the navigator is a new important trend in the educational evaluation methodology and the discovery of better human-ship systems. Knowing who is a 'ship-friendly' navigator can ultimately reduce casualties at sea.

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TERMS AND DEFINITIONS

Art: An ability or skill that a navigator can develop with training and practice including his sense and sensitivity of the unconscious/subliminal level.

Bridge Design: The ship's bridge design depends on the ship's shape which a ship builder decides mainly by aiming at the efficient cargo storage for each kind cargo (e.g. oil, gas, cars, containers etc.). The design elements consist of outer and inner design: the outer design elements are a position on the ship, a size, a shape and the inner design are a layout of some navigational instruments (e.g. gyro compass, Radar, steering stand etc.) and windows. The navigator centered bridge design is also important to prevent the human errors for attempting safe navigation [25].

Bridge Team: In the ship's bridge team, the teammates are a captain, deck officers and quartermasters. The members on the bridge differ according to watch conditions which depend on geographical and weather conditions. Moreover, these conditions are divided into four conditions including some situations - Fog, Heavy traffic, Entering a channel, harbour or restricted area, Heavy weather and Fire, flooding, or other emergency. 1) All clear conditions on manoeuvrability, weather, traffic and systems. A deck officer and a quartermaster can handle the bridge watch, and sometimes a deck officer alone does it, 2) Somewhat restricted visibility, constrained geography and congested traffic. A deck officer and a quartermaster can handle the bridge watch, 3) Serious poor visibility, close quarters – in bay and approach channels, and heavy traffic. A captain, a deck officer and a quartermaster can handle the bridge watch, 4) On Berthing

and anchoring, a captain, a deck officer, a quartermaster and pilot at special locations in the bridge can handle the bridge watch. A chief officer and bosun are at the bow station, and a second officer and deckhand are at the stern station.

Bridge Resource Management (BRM): The navigator utilizes all bridge teammates and all instruments for attempting safe navigation to prevent human errors in the early stages. Especially, the management for the bridge team is called “Bridge Team Management (BTM)” [26].

Heart Rate Variability: The heartbeats consist of P, Q, R, S and T wave. R wave is remarkable for the amplitude in comparison with other waves (P, Q, R and S), and it is easily detected. The interval from R to the next R is fluctuation, and its frequency components, low frequency 0.04-0.15 Hz and high frequency 0.15-0.40 Hz, are in relation to the sympathetic nervous system and the parasympathetic nervous system. These frequency components are used to evaluate the mental workload [27], [28].

Homeostasis: Biological objects (e.g. human, animal) always maintain stability of cell activity in the internal environment of the body. The internal organs also do it with the activity of hormones and nerves. The human keeps the stability unconsciously.

Navigation: In ship’s navigation, navigation is defined as “the art of conducting a vessel from one place on the earth’s surface to another by sea safely, expeditiously and efficiently” or “a sea trip from a departure place to going back to the place” or “a long way sea trip” [29], [30]. The safe, expeditious and efficient navigation is accomplished by the navigator’s well-honed cognition and judgment under his synthesized knowledge and experience.

Ship’s Bridge Simulator: In ship’s education and training, there are four kinds of simulators- ship’s bridge simulator, RADAR (Radio Detection and Ranging) simulator, engine simulator and GMDSS (Global Maritime Distress and Safety System) simulator. The ship’s bridge simulator is used to educate students about ship handling which is almost like actual ship’s training. The simulators in the Japanese maritime schools usually have no motion base system with which the bridge moves for six degrees of freedom (roll, pitch, yaw, sway, heave and surge). Rather, the picture shown by the visual system simulates it.